Submitted to: EPAC 2002
Paris, France, June 2-7, 2002

BNL-69227

RHIC Collimator Performance *

A. Drees, R. P. Fliller III, D. Gassner, G. McIntyre, D. Trbojevic, BNL, Upton, NY, 11793

Abstract

The limiting aperture in the Relativistic Heavy Ion Collider (RHIC) are the abort kicker magnets. It was found that during ramps there were continuous, and particularly high losses at this location due to orbit distortion and emittance growth. These losses can deteriorate the ferrite in the kicker and reduce its performance. Losses at store also caused backgrounds in the experimental detectors. The collimators were used to reduce these losses along the ramp, as well as experimental backgrounds during the store.

1 INTRODUCTION

Beam halo, large beam profiles and beam losses induce high experimental backgrounds throughout the stores as well as contribute to the reduction of the lifetime of accelerator components. In superconducting machines quenches due to uncontrolled beam losses during beam steering, the acceleration ramp or fault conditions are likely. Collimators used as the limiting aperture can help prevent damage.

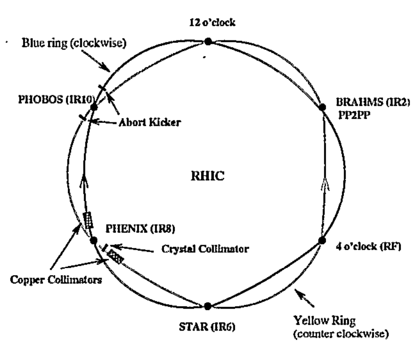

Figure 1: *Location of the collimators and experiments in the RHIC rings.*

The RHIC run in the year 2001/2002 consisted of a heavy ion run (Au-run) followed by 8 weeks of polarized proton operation (pp-run). Both runs had different needs for collimation. During the Au-run several ramps were introduced implementing β^*-squeezes from 10 m to 5 m, from 10 m to 2 m and finally from 10 m to 1m (at PHENIX only). There were no squeezes during the proton run, instead $\beta^* = 3$ m was used for injection as well as storage for all IRs. Figure 1 sketches the geometry of RHIC with the collimators and the five RHIC experiments.

2 LAYOUT

The RHIC collimation system [1] layout is shown in figure 2. It consists of two 450 mm long L-shaped copper

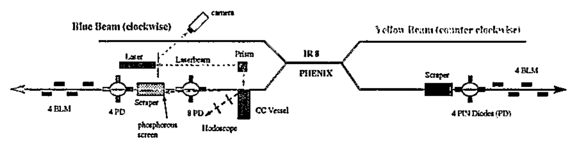

Figure 2: *The RHIC collimation system*

scrapers placed downstream of the PHENIX detector in each ring. Each collimator is moved by three stepper motors, which control the horizontal and vertical positions and rotate the collimator about the vertical axis. The step size is approximately 0.5 μm. Fully retracted the vertical jaws are about 56 mm and the horizontal jaws about 52 mm from the center of the beam pipe. In addition the yellow (counter-clockwise) ring has a 5 mm long, O-shaped silicon crystal. The (110) crystal planes are placed at an angle of 465 μrad with respect to the normal of the input face. The crystal is bent 0.44 mrad. Eight PIN diode loss monitors between the crystal and the scraper look for scattered particles from the crystal. In addition, two scintillators are oriented such that they look at the crystal. More details can be found in [1] and [2].

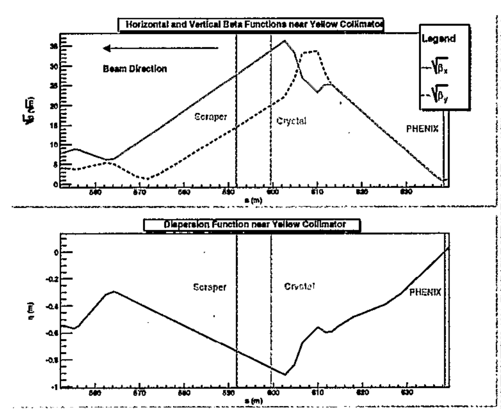

Figure 3: *Beta function (top) and dispersion (bottom) in the yellow ring close to the collimators.*

Figure 3 displays the β-function and dispersion at the location of the crystal and scrapers in the yellow ring. The values for the blue ring are equivalent. Because of the negligible dispersion, the scrapers cannot be used for momentum collimation. Since RHIC lacks any other collimators, a combination of fast kickers and the scrapers was used to excite and remove off-momentum beam particles during

* Work performed under the auspices of the U.S. Department of Energy

the last run [3].

3 HEAVY ION OPERATION

During the 2001 Au-run the ions were accelerated up to $\gamma \approx 107$. During the acceleration ramp various processes, such as orbit variations and radial shifts, are potentially leading to beam losses. It turned out that the abort system kickers [4] acted as limiting aperture. Figure 4 (top) shows

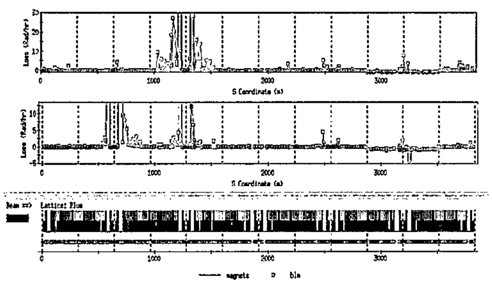

Figure 4: *Losses around the RHIC ring as a function of s during the ramp 1366 (top) and 1511 (center). The bottom graph depicts the RHIC lattice and the location of the loss monitors. Vertical dashed lines correspond to center of arcs and IRs respectively.*

the losses around the ring during a ramp on Oct. 18, 01, as a function of s, i.e. the distance from IR6. The abort kickers, situated around IR10 ($s = 1278$ m), are clearly limiting aperture causing significant losses peaking at values ≥ 100 Rad/h. When the collimators, situated around IR8 ($s = 639$ m), were used, they absorbed most of the losses as shown in fig. 4. The collimators were moved in to a predefined position during all ramps squeezing to $\beta^* \leq 2$ m, starting Oct. 26, 01.

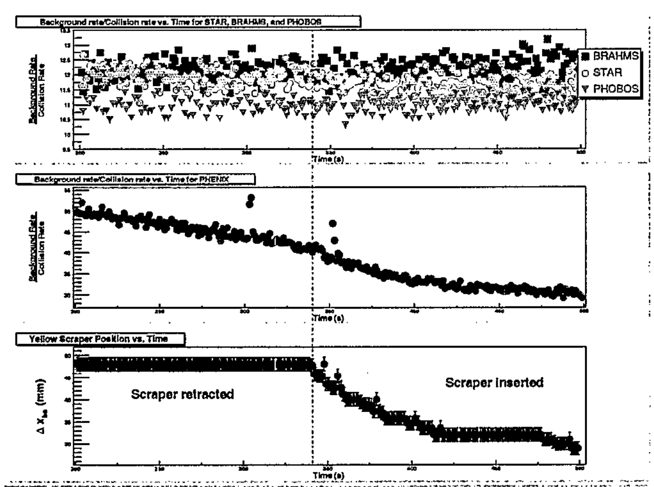

Figure 5: *Background as a function of scraper position during Au operation. $\beta^* = 2m$ at all IRs.*

The scrapers were also used in an attempt to prevent experimental background during storage. Figure 5 shows the yellow scraper position and the experimental background rates during fill 1759. The yellow collimator was moved in by about 20 mm horizontally after orienting it such that it was parallel to the direction of the beam. There is no visible effect on the background signal except a small decrease in the PHENIX rates. Apparently, the scrapers had no significant effect on the experimental backgrounds at any time during the Au-run. This leads to the conclusion that the background in the experiments is due to local causes such as beam-gas interactions or colliding beams. Attempts to use the crystal for further experimental background reduction during the Au run were unsuccessful.

4 POLARIZED PROTON OPERATION

During the polarized proton run beam was ramped to $\gamma \approx 107$ with $\beta^* = 3$ m at all IRs. There was no need to use the scrapers during the ramp and neither scraper nor crystal were used routinely at any time during the pp-run. Figure 6 shows the effect of both, crystal and scraper, on experimental backgrounds in STAR and BRAHMS. The experimental background rates are normalized to the collision rate. While the crystal has no obvious effect on the background signal in either IR, the retracted scraper increases the signal at IR6 (STAR) by 6% while decreasing it slightly at IR2 (BRAHMS). Background signals are derived from the experimental luminosity monitors, which are situated close to the beam pipe. However, when looking at other sig-

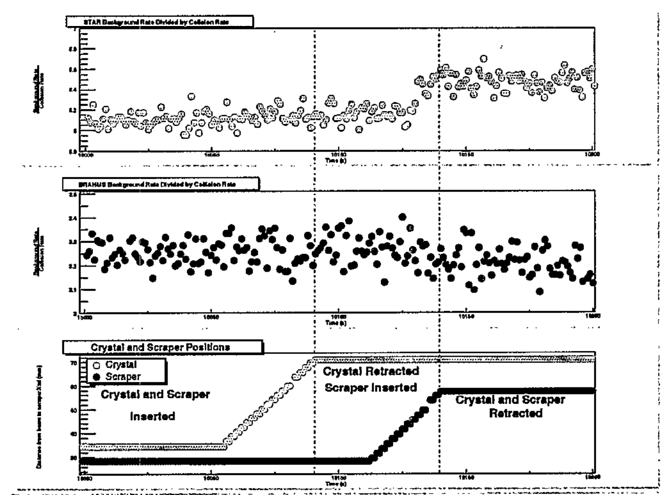

Figure 6: *Polarized Proton background as a function of collimator position during fill 2185.*

nals from STAR coming from a detector some 2 m away from the beam pipe[5], background is increased when the scraper is moved in. The results from the crystal are inconclusive since it increases as well as decreases the background compared to the scraper being in alone. In either case, the rates are higher than with both devices out by several 10%.

In figure 7 several detector signals from PHENIX are shown during a dedicated end-of-fill background study[6]. When the scrapers are moved in aggressively, the MUID1D rate drops by a factor of 8 while others, BBLL1 and NTC (both collision signals from detector components close to the beam pipe) remain constant. When beams are brought out of collision (mis-steer), those rates drop a lot while MUID1D is constant. After the collimators are pulled out,

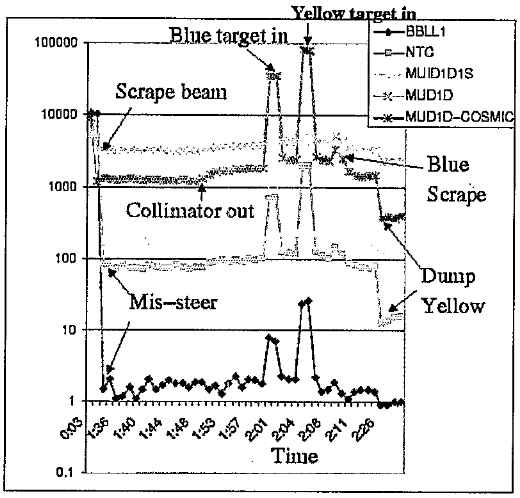

Figure 7: *Various detector signals from the PHENIX experiment as a function of time during a collimation study on Jan 21 01.*

the MUID1D signal records a 20% increase. All signals peak when the polarimeter targets are moved in and the MUID1D keeps a rate about 20% higher than before. Moving the collimators in again reduces the MUID1D signal. When one beam (yellow) is dumped, most signals drop while the single beam contribution to the background signals remains.

5 SPECIAL STUDIES

In addition to experimental background reduction, the collimators may be used to control beam emittance. Figure 8 shows the scraper position during a study done to prepare the PP2PP experiment which required low beam intensity in the presence of very small transverse emittances. The horizontal and vertical jaw of the blue scraper were moved alternately. However, both emittances are affected most by the horizontal jaw. In about 40 minutes 45% of the blue beam is removed by the scraper while reducing the emittance, as measured by the Ionization Profile Monitors (IPM) [7], by 55%. To avoid high instantaneous loss rates and a possible beam abort, the scraper had to be moved in very slowly. In addition, the profile monitors were not calibrated for pp operation and known to overestimate the beam size significantly. Therefore the data can be used to monitor relative changes only. The procedure was successfully repeated with both beams during the PP2PP run at the end of the RHIC pp operation.

6 CONCLUSION

The RHIC collimators were routinely used during the RHIC Au run in 2001. Continual losses at delicate accelerator components could be reduced significantly by making

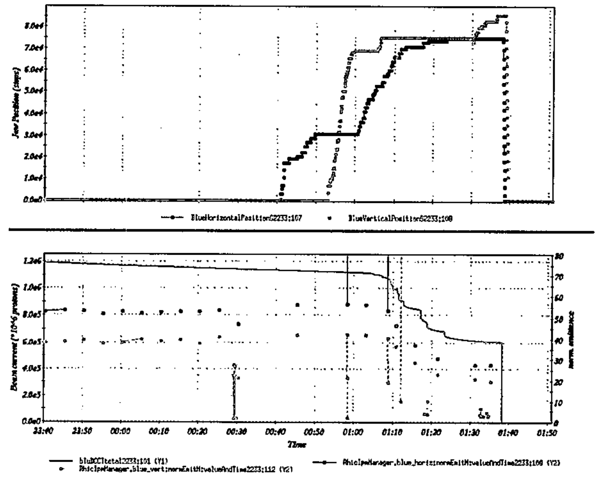

Figure 8: *Scraper position (top), beam current and beam emittance from IPMs (bottom) during fill 2233. Full range of motion was used for the scraper.*

the scrapers the limiting aperture during the ramp. However, experimental backgrounds were basically unrelated to the collimator or crystal position during Au stores. All backgrounds are likely due to causes local to the IR. The effect of the scrapers on background was still small during the proton run and varied between IRs and detector components. Although attempted, the crystal collimator could not help reducing the experimental backgrounds so far. In fact, it was shown to increase background signals at IR6 with protons by some 20%. When used aggressively, the scrapers could provide background reduction at certain IRs and minimize the transverse emittance at the expense of removing beam. For the next run we will try to enhance the crystal performance by installing a more sophisticated control electronics and a new type of crystal. To increase the scraper performance an application allowing automated positioning will be commissioned.

7 REFERENCES

[1] R. P. Fliller III *et. al.* "The Two Stage Crystal Collimator for RHIC" Proceedings of the 2001 Particle Accelerator Conference, Chicago (2001).

[2] R. P. Fliller III *et. al.* "Crystal Collimation at RHIC", these Proceedings.

[3] A. Drees, L. Ahrens et al. "Abort Gap Cleaning in RHIC", these proceedings.

[4] H. Hahn et al., "The RHIC Beam Abort Kicker System", Proceedings of the 1999 Particle Accelerator Conference, New York.

[5] W.Christie, STAR collaboration, private communication.

[6] PHENIX collaboration, private communication.

[7] R. Connolly, et al., "The RHIC Ionization Beam Profile Monitor", Proc. of the Particle Accel. Conf., New York 1999, p. 2114.